

REMARKS

INTRODUCTION:

Claims 1 - 23 are in this case. Claims 1 - 15 have been rejected. Claims 1, 3, and 11 have been amended to clarify the structure of the laser. Claim 20 is a newly added method claims and claims 21 - 23 are newly added apparatus claims.

35 U.S.C. 103(a) REJECTIONS:

Claims 1, 2 and 10 are rejected under 35 U.S.C. 103(a) as unpatentable over U.S. Patent No. 5,715,263, "Fibre-Grating-Stabilized Diode Laser" issued February 3, 1998 to Ventrudo, et al. (hereinafter "Ventrudo") in view of U.S. Patent No. 5,870,417, "*Thermal Compensators for DBR Laser Sources*", issued February 9, 1999 to Verdiell, et al. (hereinafter "Verdiell").

These rejections are respectfully traversed.

It is well established in order for a combination of references to make a claimed invention obvious, the references must teach or suggest every limitation of the claim. Furthermore, a suggestion to make the proposed combination must be found in the references. In re Vaeck, 947 F. 2d 488, 493 (Fed. Cir. 1991). Courts have also held improper a rejection under 35 U.S.C. Section 103 where "a reference would require a substantial reconstruction and redesign of the elements ...as well as a change in the basic principles under which ... [the] construction was designed to operate". (Application of Ratti, 270 F.2d 810, 813, 123 USPQ 349 (CCPA 1959)).

Communications lasers generate light energy for carrying information. Modulation is the process of placing the information into the light for transmission. Multimode communications lasers, such as the low cost multimode laser of the invention, are typically directly modulated or gain switched. Unlike lasers used in other applications, such as providing light energy to a pumped laser, multimode

communications lasers are not run continuously. They are turned on and off at the modulation rate by controlling the applied current.

The modulated light is then propagated through an optical transmission path to an optical receiver that demodulates the light waves to recover the information. Optical communication systems have generally developed along two tracks. Long haul systems, typically over 100 km, use single mode transmission over single mode fiber. Long haul systems are generally characterized by low loss and high data rates. Optical transmission systems operating below 100 km, including metro applications and local area networks (LAN) typically comprise multimode transmissions and relatively inexpensive multimode fibers. (Specification, pg. 2, line 13). These systems generally have higher losses and lower data rates than long haul systems.

Single mode and multimode systems both experience various types of chromatic and polarization dispersion. Dispersion is caused by various physical properties of optical fiber waveguide and complicated by the variation of those properties with environmental factors. Signal distortion caused by Optical waveguide induced dispersion includes time shifting and variations in polarization as a function of wavelength. The net result of the various dispersion errors is a distortion of the transmitted waves. This distortion becomes increasingly problematic as data rates increase. Single mode transmissions over single mode fiber, suffer least from dispersion and polarization errors and allow the highest data rates. This is because there are fewer frequency components in the transmitted waves, thus no additional modes.

Single mode systems, however, come with a high price tag. The various types of single mode communications lasers and associated gratings must maintain very tight wavelength tolerances such that they emit light only at the precise center wavelength. Any variation from that wavelength introduces errors that preclude operation at the required high data rates.

Single mode lasers and associated gratings, generally achieve precise wavelength control by a combination of active temperature regulating devices and

feedback and control loops to control the temperature regulating devices (e.g. solid state Peltier heat pumps). The cost of the complete single mode systems, including temperature controls, remains high. Typical multimode lasers, in contrast can have broad output spectra, are far more economical than high tolerance single mode lasers. But, due to dispersion errors, such systems suffer from relatively low bandwidths. The problem is to develop a low cost optical transmission system suitable for high transmission rates.

The inventors realized that the solution to the need for a low cost high data rate optical transmission is to employ in a WDM or DWDM a multimode laser emitting *at only a few modes*. This is a significant departure from past practice in the art, where it was believed that any additional modes would preclude high data rates. In addition to teaching that high speed optical data transmission is possible using such a laser, applicants disclose and claim a low cost optical laser suitable for such operation.

Claim 1 calls for an external cavity laser comprising a gain medium comprising a an active region, a beam expanding region, and an antireflective layer on a first surface of the gain medium. The inventive communications laser operates as an external cavity laser. That is, the external cavity comprising a reflective grating, is required for lasing and there is no lasing without the external grating. This feature of the invention is caused by the use of the antireflective (AR) coating on the first surface of the gain medium. Thus, the key operating feature of the inventive laser is that the few coherent modes that do lase are determined largely by the bandwidth of the reflective grating and the physical properties of the short external cavity. In other words photon intensity can only be reinforced and coherent gain achieved in those few modes that are within the external grating's bandwidth.

Claim 1 also provides for simultaneous emission in a few modes. And, the power in a particular mode is permitted to vary with time and environmental factors, *but the net average transmitted power remains essentially constant*. Thus complex and costly temperature regulating devices and control loops are no longer needed.

Yet another limitation of claim 1 is that light passing through the AR layer is coupled into the optical waveguide containing the external cavity and grating through a simple low cost beam expanding region. The beam expanding region facilitates butt coupling between the gain medium and a simple cleaved end of the optical waveguide. (Specification, page 7, line 13). The simplicity of this cleaved optical junction is in stark contrast with the previous complex method of coupling to optical waveguides by lenses or fibers with ends crafted as lenses. This inventive feature is important in that it helped to further lower the cost of this new type of “few mode” communications laser.

The Examiner alleges that the combination of Ventrudo and Verdiell renders the invention obvious. First, as will be shown, Ventrudo is inapplicable because it operates on an entirely different principle for an entirely different application. Secondly, Verdiell is inapplicable as providing complex solutions to single mode transmission. And finally, Ventrudo and Verdiell cannot be combined because their goals are entirely different and at opposition with each other.

VENTRUDO IS INAPPLICABLE TO THE INSTANT CLAIMS:

Ventrudo is a relatively wideband multimode laser wholly unsuitable for communications applications. It is not usable in communications applications primarily because it is designed for simultaneous operation at 20 or more modes. “The invention consists of twenty or more modes of the external cavity”. (Ventrudo, col. 5, line 9). Such transmission is far too broad and is unusable for high transmission data rates.

Ventrudo operates by an entirely different principle. It is not an external cavity laser. Ventrudo calls for a fully functional laser (that can lase without a reflector in an external cavity) employing a grating in an “external cavity” to cause coherence collapse in the emission from the laser. (Ventrudo, col. 6, line 18). Ventrudo causes bandwidth spreading of the power of the lased light from an independent laser according to the bandwidth of an external grating. This spreading is designed to create a very wide bandwidth of tens of modes as contrasted with the importance of only a few modes as described in the invention. In Ventrudo, a very broad spectrum of available modes is excited and supported by virtue of the operation of the external grating *in combination*

with the reflective coating on the output window of an independently operating laser. Thus Ventrudo does not recite the limitation of an AR coating in an external cavity laser.

Furthermore, while the invention teaches a short external cavity for use in communications applications to 100 km (Specification, pg. 2, line 26), Ventrudo teaches a grating in a waveguide ranging *from a few centimeters to over 50 cm from the facet of a laser diode.* (Ventrudo, col. 6, line 20). (This placement of the external grating is in stark contrast with an actual external cavity laser having a short external cavity on the order of 100's of micrometers.) The long distance between the diode laser and the external grating in Ventrudo precludes high data rate modulation. The long photon time of travel from the laser to the grating and back make it physically impossible to modulate such light waves at rates beyond a small fraction of the transit time of the photons.

Ventrudo does not incorporate an AR layer because the laser in Ventrudo is not an external cavity laser. It is a grating-stabilized laser. Moreover, the inability to do high speed modulation is not of concern to Ventrudo since his motivation is to generate light waves solely for the purpose of supplying energy to optically pump a laser or optical amplifier. Furthermore, Ventrudo teaches away from the invention by teaching emission on 20 or more modes for supplying pumping power to an externally pumped laser. Ventrudo is inapplicable to, and not useable as high data rate communications laser.

VERDIELL IS INAPPLICABLE TO THE INSTANT CLAIMS:

Prior to the invention, it was generally believed that multimode lasers were only useful for very short distance communications applications or for providing "raw" unmodulated light energy as in Ventrudo's broadband source of energy for a pumped laser. Single mode laser operation was seen as the only practical solution for most communications applications. Accordingly, inventions such as Verdiell reinforced this belief by stressing the importance of very narrow single mode emission. Verdiell "provides approaches for eliminating, reducing, or otherwise avoiding the effects of

longitudinal mode hopping ... rendering the device ... suitable for communications applications". (Verdiell, col. 2, line 62).

The instant invention can use an economical butt coupling between the output facet of the side of the gain media and the cleaved fiber end. By contrast, Verdiell discloses far more costly and complex coupling by a lensed fiber. The Verdiell tapered region is specifically designed to effectuate the optical coupling to the lensed fiber end. (Verdiell, figs. 1, 2, 6, 7, 8, 9).

Verdiell teaches away from applicant's surprising finding that simultaneous lasing on at least two modes is advantageous in many high speed communications applications such as WDM and DWDM systems. Moreover, Verdiell teaches complex coupling to an external cavity by optical lens, not a simple cleaved butt optical interface. Verdiell is therefore inapplicable to the invention.

IT IS IMPROPER TO COMBINE VENTRUDO AND VERDIELL:

Ventrudo teaches away from Verdiell. Ventrudo teaches a laser as a source of continuous wave light for the purpose of supplying broadband light energy to a pumped laser. Ventrudo teaches a laser coupled to a grating in a waveguide in a structure that is unsuitable for communications applications. Verdiell teaches away from Ventrudo by teaching that single mode emission and complex optics are required for communications lasers to avoid more than one transmission mode. There is no suggestion, teaching or motivation in either patent to cause one skilled in the art to combine them. Therefore Ventrudo in view of Verdiell does not make obvious the inventions of claims 1, 2, and 10.

Claims 6 and 13 are rejected under 35 U.S.C. 103(a) as unpatentable over Ventrudo in view of Verdiell, and in further view of U.S. Patent No. 5,780,875, "Hybrid Optical Integration Assembly Using Optical Platform" issued July 14, 1998 to Tsuji, et al. (hereinafter "Tsuji").

Claim 6 depends on claim 1, previously discussed, and claim 13 depends on a similar claim 11. Specifically claim 11 calls for an optical communications system using

the inventive external cavity laser comprising a gain medium with an AR coating on the first surface of the gain medium, and a beam expanding region coupled to a waveguide comprising a Bragg grating. Claim 11 also calls for the laser to be operated in two or more modes without temperature compensating apparatus. Thus claim 11 patentably distinguishes from the combination of Ventrudo and Verdiell for the same reasons as claim 1.

Tsuji discloses laser thermal management and the minimization of stray capacitance. Tsuji does not suggest, teach, or motivate one skilled in the art that simultaneous lasing in at least two modes is advantageous in many high speed communications applications. Taken alone, or in combination with the other references, Tsuji does not render independent claims 1 or 11 obvious. Therefore Tsuji also does not render claim 6 which is dependent on claim 1 or claim 13 which dependent on claim 11 obvious.

Claims 7 and 14 are rejected under 35 U.S.C. 103(a) as unpatentable over Ventrudo in view of Verdiell, and in further view of U.S. Patent No. 6,195,485, "Direct-Coupled Multimode WDM Optical Data Links With Monolithically-Integrated Multiple-Channel VCSEL and Photodetector" issued February 27, 2001 to Coldren, et al. (hereinafter "Coldren").

Coldren describes a system comprised of vertical cavity surface emitting lasers (VCSEL). This technology is believed inapplicable to an external cavity laser operating at two or more modes. Coldren is proffered as teaching a bit error rate of less than 10^{-12} .

Taken alone, or in combination with the other references, Coldren does not render independent claims 1 or 11 obvious. Therefore Coldren also does not render claim 7 which is dependent on claim 1 or claim 14 which dependent on claim 11 obvious.

Claims 3, 4, 5, 8, 9, 11 12, and 15 are rejected under 35 U.S.C. 103(a) as unpatentable over Ventrudo in view of Verdiell, and in further view of U.S. Patent No.

5,978,400, "Laser" issued November 2, 1999 to Campbell, et al. (hereinafter "Campbell").

Campbell discloses an optical waveguide directing optical radiation at an angle to the normal of the front facet of the gain media of laser. (Campbell col. 2, line 23).

Campbell does not suggest, teach, or motivate one skilled in the art that simultaneous lasing in at least two modes is advantageous in many high speed communications applications. In fact, Campbell states that such characteristics are "not generally considered suitable for telecommunications" applications. (Campbell, col. 4, line 30).

Taken alone, or in combination with the other references, Campbell does not render independent claims 1 or 11 obvious. Therefore Campbell also does not render claims 3, 4, 5, 8, or 9 which are dependent on claim 1 or claims 12 and 15 which dependent on claim 11 obvious.

CONCLUSION:

Regarding independent claim 1, as described above, Ventrudo in view of Verdiell does not render claim 1 obvious. Claim 1 is drawn to an external cavity laser for communications applications operating on 2 or more modes, comprising a gain medium comprising an active region, a beam expanding region, and an antireflective layer on a first surface of the gain medium with a simple low cost beam expanding region that doesn't require lenses. Ventrudo does not disclose an AR layer and teaches away from the application by suggesting very broad band operation on 20 or more modes. Verdiell teaches the need to maintain one and only one single mode. There is no suggestion, teaching, or motivation to combine Ventrudo and Verdiell. Therefore, the recited combination does not render the invention obvious.

Regarding independent claim 11, the Examiner asserts that addition of Campbell, teaching a short cavity, and Dugan, teaching a long haul system, to the combination of Ventrudo and Verdiell, makes claim 11 obvious. It is unnecessary to argue the merits of Campbell or Dugan because neither one taken alone, or in combination remedy the

deficiencies of the combination of Ventrudo and Verdiell. Therefore the cited references do not render impendent claim 11 obvious.

Regarding the dependent claims, the examiner adds further references over the combination of Ventrudo and Verdiell. None of the additional references, taken alone or in combination correct the deficiencies of Ventrudo and Verdiell. Therefore the additional cited references do not render the dependent claims obvious.

In view of the foregoing, it is respectfully submitted that claims 1 - 23 patentably distinguish from the cited art. Accordingly, this case now fully complies with the provisions of 35 U.S.C. Sections 103 and is now in condition for allowance. Reconsideration and favorable action in this regard is therefore earnestly solicited.

Respectfully submitted,



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Amended claims showing changes:

1. An optical communication system comprising an external cavity laser that comprises:

a gain medium comprising an active region, a beam expanding region, [and] a first surface having a reflective face and a second surface having an antireflective layer [on a first surface of the gain medium];

an optical waveguide located adjacent the gain medium such that at least a portion of the electromagnetic energy generated by the active region passes through the beam expanding region and through the antireflective layer into the optical waveguide; [and]

a Bragg grating integral with or coupled to the optical waveguide,

wherein the gain medium and the optical waveguide exhibit a coupling efficiency [of at least 40% with or] which, even without the presence of coupling optics located between the gain medium and the optical waveguide is great enough that during laser operation, substantially all optical resonance that occurs is resonance of the cavity defined between said reflective face and said grating; and

wherein the laser is configured to provide multimode output of at least two modes within the grating bandwidth.

3. The system of claim 1, [wherein the gain medium comprises a cavity less than 1 cm in length.] wherein the cavity has a length of less than 1 cm.

11. An optical communication system comprising an external cavity laser that comprises:

a gain medium comprising an active region, a beam expanding region, [and] a first surface having a reflective face and a second surface having an antireflective layer [on a first surface of the gain medium];

an optical waveguide located adjacent the gain medium such that at least a portion of the electromagnetic energy generated by the active region passes through the beam expanding region and through the antireflective layer into the optical waveguide; [and]

a Bragg grating integral with or coupled to the optical waveguide,

wherein the gain medium and the optical waveguide exhibit a coupling efficiency [of at least 40% with or] which, even without the presence of coupling optics located between the gain medium and the optical waveguide is great enough that during laser operation, substantially all optical resonance that occurs is resonance of the cavity defined between said reflective face and said grating; and

wherein the laser is configured to provide multimode output of at least two modes within the grating bandwidth,

wherein the laser is operated by direct modulation,

wherein the laser is operated in the absence of a temperature-compensating apparatus,

wherein the gain medium comprises a cavity less than 1 cm in length, and

wherein the length of the system is less than 100 km.

New Claims:

16. The system of claim 1, wherein the coupling efficiency between the gain medium and the optical waveguide is at least 40%.

17. The system of claim 1, wherein the optical communications system comprises a WDM or DWDM system.

18. The system of claim 11, wherein the coupling efficiency between the gain medium and the optical waveguide is at least 40%.

19. The system of claim 1, wherein the optical communications system is a WDM or DWDM system.

20. A method to achieve high data rate modulated laser transmissions in an optical network by:

providing an optical laser which includes a gain medium having a reflective face, and further includes an external cavity effectively terminated by a grating having a bandwidth;

providing an optical fiber;

operating the optical laser such that laser radiation is produced in at least two modes within the grating bandwidth;

through the use of a light-expanding region and an antireflective (AR) layer, coupling light between the gain medium and the external cavity such that substantially all optical resonance that occurs is resonance of the cavity defined between said reflective face and said grating;

applying a modulation signal to the optical laser, thereby to produce modulated light; and

launching the modulated light into the optical fiber.

21. A multimode laser, comprising:

a gain medium having a reflective face, a beam-expanding region, and an antireflective (AR) layer;

an optical waveguide located adjacent the gain medium such that at least a portion of light output from the gain region passes through the beam-expanding region and through the AR layer into the optical waveguide; and

a grating defined in the optical waveguide, said grating having a bandwidth;

wherein the gain medium and the optical waveguide exhibit a coupling efficiency which, even without the presence of coupling optics located between the gain medium and the optical waveguide, is great enough that during laser operation, substantially all optical resonance that occurs is resonance of the cavity defined between said reflective face and said grating; and

wherein the laser is configured to provide multimode output of at least two modes within the grating bandwidth.

22. The multimode laser of claim 17, wherein the light output from the gain region is butt-coupled from the AR layer to a cleaved end of said optical waveguide.

23. The multimode laser of claim 17, wherein the light output from the gain region is modulated by direct modulation.